Floaters and Sinkers

Synopsis

Students will gain an intuitive understanding of density by comparing objects of equal volumes but which have different masses. They will then use two different methods to determine the densities of a variety of materials and objects. The first method involves direct measurement of the volume of objects that have simple shapes, while the second uses the water displacement method to determine the volumes of irregularly-shaped objects. This exercise is intended to follow the exercise **Clay Boats**.

Objectives

Students will be able to define density as the amount of mass per volume a material contains, and be able to compare the densities of several types of materials, especially those that sink in water compared to those that float. Through their investigations, students will meet Competency Goal 4 of the *NC Standard Course of Study* for seventh grade science, "The learner will build an understanding of the general properties and interactions of matter." This exercise specifically addresses Objective 4.03, "Analyze the suitability of materials for use in technological design: density"; and Objective 4.04, "Classify objects based on characteristics: density."

Materials

- Several small, identical boxes, *e.g.*, empty diskette boxes, each filled with different materials, such as uncooked rice, dry cereal, M&M's™ candy, and sand. (These can be taped shut to prevent leakage.) You will need one box per team of four students, but some of the boxes can duplicate the materials inside. If your class size requires seven boxes, for example, you do not need to have seven different materials -- instead, two might be filled with rice, two with cereal, two with sand, and one with candy.
- An assortment of small objects for which students will determine densities by first measuring dimensions and then calculating volumes. This assortment should consist of objects whose shapes are regular (rectangular prisms, spheres, or cylinders) such as metal bars; blocks of wood; marbles; Fire Balls™ candy; corks; candles; art gum erasers; and modeling clay that can be molded into cubes or spheres.
- A second assortment of objects that have irregular shapes; their volumes will be determined by the displacement of water. This group can include rocks; small figurines (*e.g.*, plastic soldiers or animals, metal or ceramic figures, *but note*, they should be made of only one material); large nails or bolts; short lengths of metal chain; pieces of broken brick, pottery, or Styrofoam™; and vegetables such as carrots or potatoes (or chunks thereof).
- rulers, at least one per team
- calculators, one per team

- balances accurate to 0.5 g (*e.g.*, standard triple beam balances), one per team
- 25, 50, and 100 mL graduated cylinders, at least one per team (ideally one small one plus one of the larger ones per team)
- 250 and/or 500 mL beakers, one or both per team
- pans or trays to catch water that overflows from the beakers during the displacement process, one per team
- funnels to fit into the tops of the graduated cylinders (optional, but they help limit the amount of spilled water), one per team
- sponges and/or dishrags (for wiping up drips and spills), at least one per team
- thread

Procedure

In this exercise, students will first be led to the idea of density as a way to compare materials based on how much "stuff" (matter, mass) is packed into a certain volume. Start by showing the class three or four boxes that appear to be identical, for example, diskette boxes, or boxes that once held macaroni and cheese dinners. Each box, however, should now be filled to the top with a different material. One box might contain uncooked rice or popcorn, another dry cereal or popped popcorn, a third M&M's™ or other candy, and the last sand. (These are just examples -- other substances will do, as long as they represent a range of masses for the given volume of the boxes.) Let students handle the boxes, but do not let them open the boxes. It would be a good idea to tape them shut, anyway, to prevent leakage. Then ask the class to compare the features of the four boxes, writing their observations on the board.

They should note that the boxes look identical, so be sure they refine this observation to include the idea that their volumes are identical. They should also note that the boxes had different weights, or masses. Once these two observations have been made, you can let students know there is one word that includes both of those observations. That word is *density*. Density tells us how much material is packed into a given amount of space. It tells us how the masses of two different objects would compare if they both had the exact same volume.

The dry cereal (or popped popcorn) is not very dense. The material in the box does not weigh very much, largely because there is a lot of air occupying the spaces between the cereal flakes (or between the popped corn kernels, which themselves contain a lot of air, too). The candy and rice grains are more dense; they can pack together more tightly in the box. Sand grains can pack very tightly together, and so the box containing them is the densest of all.

Once students understand the idea of density, ask them how it could be *quantified*. Point out that we use meters for describing length, degrees for describing temperature, and miles per hour for describing speed. What units should we use for describing density, if it is the amount of material that fits into a given volume? Give them a few minutes to grapple with this problem, and they should be able to identify mass (or weight) and volume as the quantities needed. They may have more trouble realizing that mass needs to be divided by volume, however. Density is defined as the amount of mass per volume of a substance, and it may help to tell students that *per* always means *divide*. (They are probably already familiar with speed: to find the speed, they divide the miles traveled by the hours it took to travel them, to get miles *per* hour.)

Give each team of students one of the boxes and ask them to determine the density of that particular box. Again, let them figure out that they will need to find the mass of the box, as well as measure its dimensions to calculate the volume. As students begin to measure the boxes, tell them to make their measurements in centimeters, so their volumes will be given in cubic centimeters. Once they have made their calculations, write the densities (including the units, g/cm^3) on the board. Have students check to make sure their answers make sense (they should all be greater than one, and the heavier boxes should, of course, have higher densities.

Next, invite students (who are still working in teams) to determine the densities of the objects in the first assortment listed in **Materials**. Create a large data table on the board with room for each team to enter their results, rounding their densities to the nearest one-hundredth. Different teams should get slightly different densities for the same object, and it would be good to have students explain why these differences occur. (See also the exercise **Measurement and Variation**). Of course, if two teams get very different densities, they will need to repeat their measurements and calculations.

The table below lists the densities of a number of common materials. These densities were determined with the help of sophisticated measurement devices, but for similar or identical materials, your students should be able to produce densities that are close to those listed.

Material	Density (g/cm^3)	Material	Density (g/cm^3)
Aluminum	2.64	Iron (cast)	7.21
Brass	8.55	Iron (wrought)	7.77
Brick (red, common)	1.92	Lead	11.34
Coal (anthracite)	1.51	Marble	2.56
Concrete	2.37	Paraffin (wax)	0.72
Copper (cast)	8.68	Quartz	2.64
Copper (rolled)	8.91	Rubber	1.52
Cork	0.24	Steel (cast)	7.85
Feldspar	2.56	Steel (rolled)	7.93
Glass (window)	2.58	Wood (dry) - red cedar	0.38
Gneiss	2.87	Wood (dry) - Douglas fir	0.53
Granite	2.69	Wood (dry) - hickory	0.85
Gold (pure, 24 kt)	19.29	Wood (dry) - maple	0.70
Ice	0.92	Wood (dry) - red oak	0.70

Ivory	1.84	Wood (dry) - yellow pine	0.70

Next, present the class with the second assortment of objects, whose shapes are not regular. Ask students to work within their groups to figure out a way to determine the densities of these oddly-shaped objects. Give them plenty of time to explore this problem (5-10 minutes, perhaps). If they can't come up with the water-displacement method on their own, ask them to imagine filling a bathtub all the way to the top. Then ask what would happen if they took a gallon jug of juice and lowered it into the water. How much water would spill over the edge of the tub? What if they lowered themselves into the filled tub of water -- how much water would spill out? Would it be possible to catch and measure the amount of water that spilled out? *Note: You will need to tell students that 1 milliliter of water equals 1 cubic centimeter of water. (Students could also determine this for themselves.)*

Make the beakers, graduated cylinders, trays, and funnels available to students so that they can devise their own water-displacement methods to determine the volumes of the oddly-shaped objects. For any of the objects that float, students will have another problem to solve. They may try using a pencil point to hold the object just below the surface of the water. They could also use thread to tie the object to another, heavier object that will sink, such as a rock or piece of metal. They will then need to subtract the volume of the rock or metal from the displaced volume of water in order to obtain the volume of the otherwise floating object.

After students have determined the densities of the objects, ask them to find one more density, that of water. They may be puzzled at first, but give them time to realize that, just like the solid objects, they only need to find the mass of a known volume of water. They should know that they'll need to subtract the mass of the container for the water. Check their results to make sure they get a density close to 1.00. (They will probably find it interesting to note that the density of ice is less than that of water. Water is the only natural substance for which the solid form is *less* dense than the liquid form. It's a good thing, too! The layer of ice that floats on the surface acts to insulate the rest of the water below, keeping it from freezing solid, and thus allowing fish, plants, and all the invertebrate and microbial lake-dwellers from dying as soon as the temperature gets below freezing.)

Next, have each student create a scatter graph for the objects, in which mass in grams is on the x-axis, and volume in cubic centimeters is on the y-axis. Their graphs should look something like the one below. Have students add the dashed line that forms the diagonal to their graphs. Explain that this represents the density of water, since for pure water, the mass in grams is equal to its volume in cubic centimeters. Put another way, the ratio of mass to volume is always 1.00, as long as the units are grams and cubic centimeters.

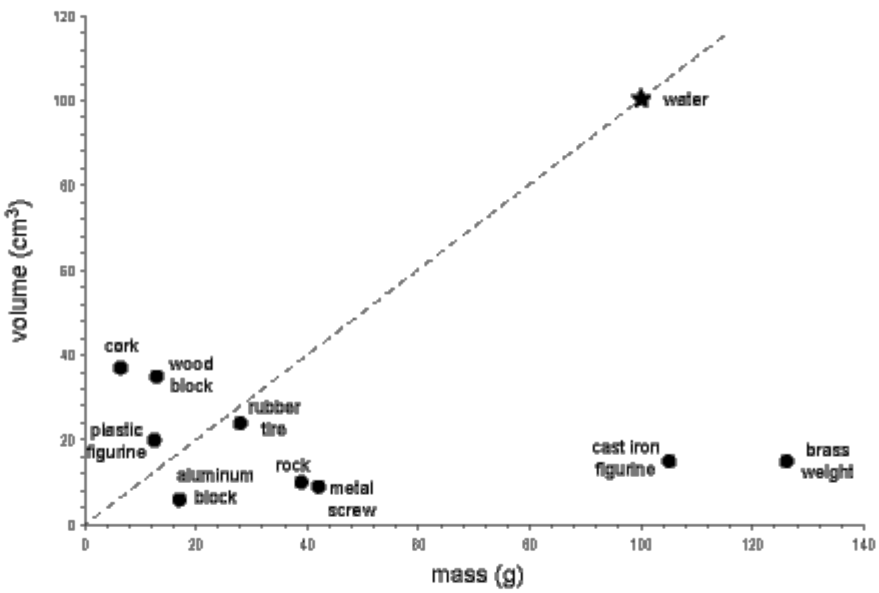

Figure 1

Discussion

Ask students what the points that lie above the dashed line have in common. Although there will only be a few of them, students should note that these are the least dense of the objects; in fact, they are the objects that float. The points for all the other objects, the ones that sink, lie below the line. In other words, they are denser than water. Make sure students understand that, ordinarily, anything less dense than water floats, and anything more dense than water sinks.

There are exceptions, however. The data points for their cubes or spheres of modeling clay fall below the dashed line, indicating that clay sinks. But in their earlier investigations of **Clay Boats**, they were able to make the clay float. So what is going on? This discrepancy leads to the next exercise, **What Floats Your Boat?**, which deals with the concept of *buoyancy*.

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